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Arctic System Reanalysis

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1. Introduction

Global reanalyses of atmospheric observations have been and are being carried out by the National Centers for Environmental Prediction (NCEP) (Kalnay et al. 1996; Kistler et al. 2001) and by the European Centre for Medium-Range Weather Forecasts (ECMWF) (Gibson et al. 1997; Uppala et al. 2000). The NCEP global reanalyses are the NCEP/National Center for Atmospheric Research (1948-today, NNR) and NCEP/Department of Energy AMIP 2(Atmospheric Model Intercomparison Project 2) (1979-today, NCEP-2) efforts. The ECMWF global reanalyses are the 15-year (ERA-15, 1979-1993) and the 40-year (ERA-40, 1957-2001, currently proceeding) efforts. The white paper by Roy Jenne gives more details. The temporal resolution is 4 times a day and spatial resolution ranges from 80 km to 210 km. The data span the Earth's surface to the stratosphere and beyond. Reanalyses combine a short-term model forecast with all available observations (from the ground, rawinsondes, aircraft, satellites, etc.) to produce optimum analyses of directly measured variables (winds, temperatures, etc.). Short-term forecasts are also run to produce variables that are incompletely monitored or unmeasured (precipitation, evaporation, clouds, radiative fluxes, etc.). A key aspect of reanalyses is the use of a fixed data assimilation system, thus avoiding artificial climate signals that are characteristic of operational analysis systems which are constantly being improved to benefit weather forecasting. However, the changing database (e.g., new satellite systems come online), data handling difficulties, and limitations to the assimilating model physics (e.g., Walsh and Chapman 1998) can lead to problems with global reanalysis products.

As an example of the continuing difficulties with global reanalyses in the Arctic, the following realization arose from initial evaluation of ERA-40 output in conjunction with the November 2001 ECMWF Workshop on Reanalyses attended by Mark Serreze and the author (Bromwich et al. 2001). For the test period of 1989-1991, there is a North Pole-centered 500-hPa-geopotential-height difference between ERA-40 and ERA-15 of -35 gpm. This annual difference decreases rapidly toward the surrounding continents, and is a little larger in summer than winter. Comparisons between the 1000-500 hPa

thickness (proportional to the layer-mean temperature) measured at radiosonde sites around the edge of the Arctic Ocean and corresponding ERA-40 values strongly suggest that there is a lower tropospheric cold bias in ERA-40 over the central Arctic Ocean amounting to 1-2 °C. The characteristics of the bias suggest that it is related to the assimilation of satellite sounder temperature information (TOVS) and perhaps the cloud-clearing algorithm over sea ice. Initial investigations by ECMWF support this supposition, but more work remains to be done to understand this bias that is also present over the Antarctic sea ice zone. Because this bias is likely due to a data-handling problem, it can be rectified relatively easily, but probably will require re-running the affected parts of the reanalysis. ECMWF expects to have a definitive evaluation of the cause of this bias shortly, and a solution to the problem. The intent of raising this issue about a new reanalysis that is still being optimized is to indicate that potential complications do exist in making use of TOVS soundings in challenging environment of the central Arctic Ocean (see the white paper by Jennifer Francis). This situation represents an opportunity for the Arctic community to optimize the use of such observations in global reanalyses.

2. Arctic System Reanalysis

One of the main tasks of SEARCH is to detect and track environmental change. Certainly global reanalyses, which integrate all available observations in a coherent framework, can be applied to this task, but as outlined above there are limitations to these global products in the Arctic. Many examples could be quoted (e.g., Bromwich 2000). For this reason, a regional reanalysis is proposed to focus on minimizing the Arctic specific limitations of previous efforts. The state-of-the-art in reanalysis is that assimilation of atmospheric and land surface observations are performed, but oceanic conditions are specified. It is conceivable that assimilation of sea ice observations could be performed (e.g., Weaver et al. 1998). For this reason, the phraseology Arctic System Reanalysis (ASR) is used. It remains to be seen how far this concept can be taken, i.e., what other types of climate system observations can/should be assimilated (e.g., atmospheric chemistry observations, river runoff).

It is proposed that ASR feature a coupled atmosphere-land-ocean reanalysis for the Arctic defined at the equatorward edge by the headwaters of the major northward flowing rivers. It is anticipated that ASR will be driven at the lateral boundaries by a global reanalysis like ERA-40. Particular aspects that ASR could emphasize are the following:

a) Identify and apply the best parameterizations for Arctic processes, e.g., Arctic stratus.

b) Enhance the assimilation of observations. Use of TOVS data over sea ice is problematic and can readily be enhanced. Also more importance needs to be attached to the assimilation of radiosonde observations in the presence of voluminous TOVS data. Another example is the correction of biases in

radiosonde observations; is it possible to develop optimum corrections for Arctic conditions, such as for the measurement of relative humidity?

c) Fully exploit the information content of remote sensing observations. Passive microwave observations of land snow extent and their liquid water content need to be fully utilized.

d) Assemble a comprehensive set of Arctic observations, especially from the former Soviet Union. There is little doubt that historical observations of precipitation and from radiosondes could be greatly supplemented.

The aim of ASR is to place the dramatic Arctic changes of the 1990s within the long-term perspective and thus to contribute in an important manner to the goals of SEARCH. If ASR is continued into the future it can monitor future environmental change in the Arctic. However reanalysis demands extensive skills in assimilation, a comprehensive database, and attention to detail. Careful consideration is needed as to how to proceed.

3. The Way Forward

NCEP is planning a regional reanalysis for North America based on the Meso Eta Model (see http://www.emc.ncep.noaa.gov/mmb/mesoscale.html under Regional Reanalysis). The horizontal resolution will be 32 km with 60 levels in the vertical. It will span 1982-2003. It will feature 3DVAR (like ERA-40) assimilation, direct incorporation of satellite radiances, and exploitation of observed precipitation. A one-year test assimilation at 80-km resolution has been completed. The domain covers all of North America, extends to the North Pole, and includes Greenland. Thus, all important Arctic atmosphere, land surface and ocean environments are sampled.

As a way to get started with ASR the following is proposed:

a) Access the NCEP regional reanalysis output for the test year.

b) Assess the performance against observations and evaluate the parameterizations of Arctic processes.

c) Explore the possibilities for ASR collaboration with NCEP. They will be the recipients of the so-called "Big Merge" between NCEP and ECMWF databases as a result of ERA-40. Could their reanalysis model and immense database be ported to another (ASR) computer system? (Initial indications are that the answer is yes.) What role would NCEP like to play in this effort?

d) Identify what changes and improvements are needed to the NCEP regional reanalysis for optimal performance in the Arctic.

e) Evaluate the horizontal and vertical resolution is needed as well as the duration of ASR. Identify the lateral boundary forcing to be used for ASR.

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